TITLE: Battlefield Information Systems in Air Warfare

Battlefield Information Systems in Air Warfare

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"Les choses simples sont difficiles à expliquer" Henri Matisse.

"If you know the enemy and know yourself, you need not fear a thousand battles. If you know yourself and not the enemy, for every victory you will suffer a defeat. But if you know neither yourself nor the enemy, then you are a fool and will meet defeat in every battle." Sun Tzu Circa 510 B.C.

Abstract

Intelligence systems are designed to enable self-knowledge and knowledge of the opposition to achieve knowledge superiority. The basis for knowledge is the collection, collation, interpretation and dissemination of information. Superior performance in the marshalling of information sources, the creation of shared knowledge and the projection of information in future plans represents what has been called information superiority (Endlsey and Jones, 1997).

Almost all stages of knowledge development involve interpretation and the introduction of selective filtering or emphasis. The integration of computers and communication systems afford the capability to share large volumes of highly processed information. There is a significant difference between information and knowledge in that the creation of knowledge involves the imposition of this interpretive framework to organize and group information in meaningful ways. Often information must be filtered to remove noise and to exaggerate the salient points. In addition, assumptions concerning the validity of the information sources must be exercised to ensure that deception and sensor capabilities are taken into account.

The construction of this shared reality amongst the users of the system depends on social, cognitive and experiential processes guiding the flow and management of information. The situational awareness of the team operating the information systems is a vital part of the effective operation of the system because it helps to direct cognitive resources and support filtering of task-and context-irrelevant information. It is possible that "the knowledge of results when attention is allocated to a zone of interest" (Fracker, 1988) are poorly articulated across the team and this results in obfuscation of the prioritized goals or the context. This is important because of the likely relationship between situational awareness and the quality of the decision making process (Endsley and Jones,

[1] This report has been written wholly by the first author and he accepts full responsibility for the contents of the document. However, significant elements of the reports were influenced by numerous discussions with the other contributors and by papers submitted by co-authors elsewhere.

Paper presented at the RTO HFM Symposium on "Usability of Information in Battle Management Operations", held in Oslo, Norway, 10-13 April 2000, and published in RTO MP-57.

1997). Team situation awareness is more complex than additive models of individual situational awareness as some have suggested (Klein, 1993) and simply aggregation of collective inputs may not adequately predict performance outcomes (Salas, Prince, Baker, Shrestha, 1995).

The design of any large-scale socio-technical system for sharing, processing and managing information resources requires careful analysis in the development, implementation and operation to ensure that the system contributes effectively to the performance it is intended to support. Many analyses of such systems focus on process variables without establishing their relationship to outcomes. For example, it has been found that communication measures may actually fail to predict performance outcomes because they do not address the mediating process of knowledge realization across the team (Cook, Angus, Brearley and Stewart, 1998). This finding has been recently supported by work demonstrating that communication may not change significantly even though the cognitive capacity to use the information exchanged does across the day (Reid, 2000). In addition, it has been shown that more commanders may actually send fewer messages to their teams but spend more time planning (Artman, in press).

What seems to be critical is the capacity to process information further to create the comprehension stressed by Endsley (1995, 1996) as a form of second level situation awareness. This is in accord with the view that the process of making or creating knowledge for decision making is more instrumental in preventing faulty decision making than processes of review given the time constraints of many military tasks (Cook, Angus, Brearley and Drummond, 1998). There are many examples in the literature where the processes of intelligence development, or operation, or both have been poorly managed with catastrophic consequences.

It can be argued that the reasons for such system level failures in socio-technical information systems can be traced to three perspectives that are inappropriately expressed in the design and operation (see Flowers, 1996; also Luff, Heath and Greatbach, 1994). The first perspective concerns the user(s). As Artman (1999a) has expressed very cogently the user is often denigrated in the development process as the root of many problems and the newly developed system(s) are intended to manage the user's behaviour to achieve greater levels of performance. Thus, so-called user-oriented design is only a rhetorical statement concerning the existence of contact with the user-population and not a guarantee of the effective elicitation of user requirements nor is it a tacit acknowledgement of the central role of users in decision-making processes.

The second perspective concerns the potential different user groups, or system clients, and the way that information sharing is prioritized among the different groups in relation to their air warfare roles. Air warfare in the form of composite air operations is a complex process of integrating diverse assets effectively and one of the factors that may determine the success of this annealing of assets across and within packages is the use of information systems (Directorate of Air Staff, 1999).

The third perspective concerns the effective operation of the battlefield information systems in a diverse range of contexts both in space-time and in composition. Failure to acknowledge the large array of factors that shape performance in the use of information systems can undermine the operation effectiveness of deployed systems. Indeed, it can be argued that operational issues and limited foresight in design can be good examples of the latent pathogens that may generate total system failure in the complex systems (Reason, 1990, 1997).

Cunning Cavemen and Dumb Machines

One of the concerns of Artman (1999a) was to draw attention to the assumptions underpinning many system developers views in relation to the user population their systems were designed to support. Artman felt that on the one hand there was a tendency to focus on the negative attributes of the human and on the other, to dwell upon the strengths of machine intelligence. This bias in the reporting of capability was clearly problematic for a number of reasons. First, the human being was the final line of control and it was the human being that would take the crucial decisions. Thus, it was important to address the user's needs in more than just the palliative sense, which many information technology projects do at present. Second, the capability that machines have is more focussed on basic information processing and any notions of so-called intelligent or adaptive function are both rudimentary and costly to validate at present. Thus, the thinking and deciding is left to the human operators and managers.

In relation to total system function there is no doubt that the raw and unflagging power of computers in processing information is valuable. The new links between computers, that enable high-speed digital exchange of information via secure networks, are both attractive and valuable in maximizing the cognitive resource utilization of all participants. It is clear that "Operation Allied Force highlighted the blending of tactical implications with strategic issues – the blend being in the cockpit, where the pilot is the final part of the decision loop." (Penney, 1999, p.32). This integration of the front-line crews in the decision making process should be made with care to ensure that the limited cognitive capacity of the busy pilot is not overloaded and part of that process must include a credible sharing of information.

Pilots also need to develop confidence in their decision making because they need to feel able to take decisions without balancing constraints. Thus, one would imagine benefits of effective and knowledgeable support from fighter controllers with the role-specific knowledge, directing the information flow and negotiating appropriate actions with front-line crews. The concern with the quality of the fighter controllers is something which has been raised before (McManners, 1996) and it shows the way in which the cognitive and social skills of the individuals in any system shape the performance outcomes. It is clear that the human element is important because of the way that human operators are often called to account for failure. However, human and system operations are intertwined and ineffective design can generate inappropriate performance.

The information must be presented to human operators in a form and at a time in which it is possible and feasible to influence the on-going course of events. Human operators need to keep ahead of the curve and when they fall in line with it or behind it the potential for erroneous decision making is great. At present the use of technology fails to maintain an intelligently managed dialogue between the human and machine intelligence, with much of the workload associated with dialogue management reliant on the somewhat limited capacity memory of the human operator. This is even true in second order ways because operators are rarely able to interrogate systems for histories or to set timers to help them schedule activities at some future point in time. The passivity of the machine is deceptive in that for many activities the pace and temporal aspects are human driven. It is possible that the lack of context sensitivity on the part of machine intelligence is a major element of the dialogue between human and machine. Humans frequently despair of the inappropriateness of machine interruptions and the banality of the requests made.

The difficulty in designing for multiple users with differing requirements and the costs associated with disseminating information is in provision of equipment, equipment support and training. This operational complexity means that there is a tendency to centralize information system development, focussing on the needs of the key decision-maker or leader (Artman, 1999). This process of centralization may lie at the heart of the process of ineffective decision making in fostering the conditions for high workload and lowered situational awareness. In addition, this may increase the risk of Groupthink because it may tend to stifle participation in negotiated decision making. Even in military systems the social and contextual world is a constructed experience which is negotiated:-

> " A team of agents have a joint persistent goal relative to q to achieve
(a
> belief from which, intuitively, the goal originates).. .In short, the notion of togetherness, of group and teamwork is based upon the notion of joint persistent goals, which are but individual goals associated with social, namely mutual, beliefs." Conte and Castelfranchi (1995, p. 153).

This general approach to command and control has been supported by a recent paper from Artman (2000) in which negotiation is one of the mechanisms used to share information. The two other mechanisms being attentive monitoring and the use of artefacts. Those operators at the lower levels of command, without direct access to information may feel dis-empowered and unable to contribute to the discussion without access to the relevant information.

The dialogue between humans and humans, and humans and machine intelligence or agents is a clearly a crucial part of the operational effectiveness in that human cognition is situated in an operational environment or domain which stimulates mental activity. The more passive the user becomes the less effective they may become in relation the decision making in the assigned task as their awareness of relevant information collapses. In many respects this acknowledges the general observations made concerning the processes involved in building situational awareness (Endsley, 1988) and the importance of active information capture.

It is possible that inexpertly designed information systems may at one and the same time encourage decreasing numbers of exchanges between crews and afford limited access to the information required for building knowledge. Or, the number and type of exchanges may vary little from that deployed in previous systems but the ability to use and comprehend information is significantly impaired. For example, the workload of managing the dialogue may increase and reduce the amount of resource available for further processing. Or, the detailed information in the exchanges may not activate the appropriate elements of the participants' mental models and create comprehension.

Situational Awareness in Information Systems

Situational awareness is "perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future". The time horizon for these events in air warfare is rapidly changing, as there is a steady shift away from close in weapons. The modern air-to-air capability of air-to-air (Clancy, 1995; Francillon, 2000; Ripley, 1994; Spick, 1995, 2000; Thornborough, 1995; Nordeen, 1999) and air-to-ground systems (Clancy, 1995; Ripley, 1994, 1999; Spick, 1995, 2000; Thornborough, 1995) which makes it is an increasingly demanding environment in terms of the forecasting of future events and interpretation of the current context.

The recognition of the interacting elements of the design equation is crucial to the effective development of battlefield information systems. While the visible coupling of the current context and future events is further apart in imagined space and time; the actual time available for effective corrective action is growing shorter. It may also weaken the ability to link the current actions with the future outcomes and generate more uncertainty. This increasing closure of the intelligence cycle in information systems in terms of time is well illustrated by the use of the JSTARS system or UAVs in the Gulf War to directly guide the actions of forces. An increase in pace and ferocity that has continued with the recent campaigns (Kromhout, 1999).

> "Thus, the J-STARS aircraft, which took radar images of enemy troops moving across the desert from a safe distance, were able to patch their radar pictures directly to the operational fire-control cells in the coalition divisions below, enabling the gunners to select and engage targets at will, without any reference to intelligence." Hughes-Wilson Col. J. (1999) Military Intelligence Blunders. p.349. London : Robinson Books.

This quotation may illustrate a growing tendency towards an increasingly shorter intelligence lifecycle, short-circuiting certain elements of the process. This may be part of an imperative in practical terms to attack mobile targets that can be quickly re-positioned or to use intelligence when it is most effective. These considerations for speed, a vital element of military operations, and the increasingly political need to exert control over the battlefield represent antagonistic forces. There are, however, very good reasons for making "real-time information directly into all cockpits" (Warwick, 1999). The implementation of this information network needs careful consideration to prevent unforeseen consequences at both higher and lower levels.

What makes military information systems vital is the way in which they can shape situation assessment. The highly dynamic characteristics of the modern battlefield require recurrent assessment of the situation to identify problems that are minor and insignificant in isolation but can develop into a major threat (Sarter and Woods, 1991). The continuous process of assimilating new information is cognitively resource intensive and effortful, and the information system must support the process effectively to prevent the operator falling out of the loop or behind the figurative curve on situation developments.

Training Development and Mental Models

Despite the difficulties in measuring mental models it is clear that they play a vital role in guiding behaviour in complex socio-technical systems. Mental models are defined as "an organized knowledge structure that includes objects, situations, and events, and the relationships between them" (Cannon-Bowers, Salas, and Converse, 1993). There is evidence that training can help develop more effective team exchanges and influence team performance (Stout, Salas, and Fowlkes, 1997a, 1997b)

Mental models are important in supporting the third element of Endsley's Situational Awareness, projection of future events. However, mental models may aid the perception and comprehension of events as well. Mental models are products of experience which may or may not be revised, re-evaluated or developed (Rasker, Post and Schragen, in press). It is to be expected that mental models acquire some degree of momentum and as they develop they become more difficult to revise substantially. In energetic terms this may explain the resistance to change a working hypothesis or some more fundamental schema, which has been operational for some time (Gilhooly, 1983).

Cook (2000) has proposed a more elaborate explanation of the typical resistance to change in a model adapted from Rasmussen's (1983, 1986) model of skill development. Rasmussen's model assumes that as a skill develops individuals change their mode or method of processing information from knowledge-based, through rule-based and on to skill-based processing. This model is widely used in the literature to explain the development of skill in the management of complex systems.

Cook (2000) has proposed that emotional and cognitive gradients encourage the skilled operator to try to remain in skill-based mode of operations even though this represents a non-optimal approach to information processing. It is proposed that the experienced operator experience anxiety when they are forced to adopt rule or knowledge-based processing which they interpret as aversive. In terms of a two-factor theory of conditioned avoidance operators are likely to learn that maintaining skill-based processing reduces anxiety induced by feelings of loss of control when they shift to rule- or knowledge-based processing. At the same time the operator will paradoxically feel safer operating in a skill-based mode of processing because they experience less demand on their available cognitive resources. This tendency towards focussed processing among experienced operators has been proposed as a potential contributing factor to accident development and may result in failure to manage more unusual system failures among experienced operators, relative to less experienced (c.f. Huey and Wickens, 1993). The tendency towards less effortful processing has been described many years ago as satsificing (Newell, 1955) but never associated with a model of skilled information processing.

It is likely that both social and cognitive processes are adaptive in complex social technical systems such as that associated battlefield information management (Cook, in press). Recognition of the part played by the team and not simply by the leader, in processing information and arriving at a decision has been strongly emphasized by Artman (1999a). Artman (1999a) has criticized the tendency towards the use of drills in using military command and control systems because of the potential shift towards automaticity of actions. Automaticity can either enhance the adaptability and flexibility, or it can increase the vulnerability of the system depending on the rigidity of the organizational culture. It is important to distinguish the use of drills and training experience in exercises when operators' responses and capability can be stretched or developed. Thus, the decision to engage multi-asset Airborne Command and Control systems in exercises is a very positive step towards effective projection of force in future engagements.

Function of Intelligence Systems

> "not just collection but of collation, interpretation, and dissemination..." Hughes-Wilson Col. J. (1999) Military Intelligence Blunders. p.5. London : Robinson Books.

Battlefield information systems have the potential to capture and transmit large amounts of information. The function of such systems is quite close related to intelligence functions as outlined in Figure 1 showing the intelligence lifecycle. What is not immediately obvious is that the process of delivering information, as in any medium, can result in distortion because decisions may be made about what to transmit to whom.

> "For the professional, intelligence is simply defined as processed, accurate information, presented in sufficient time to enable a decision-maker to take whatever action is required. Hughes-Wilson Col. J. (1999) Military Intelligence Blunders. p.5. London : Robinson Books.

All of the constituent processes can be easily distorted by time pressure and by the application of knowledge. The distortions can be effective exaggerations that reveal the priorities for action or they can be misleading or ambiguous in obfuscating the true intent of the opposition. The important issue is the ability to separate command intent and capability in intelligence analysis. The recognition of error propagation because of inferences and information selection at earlier levels in mediated systems is not new (Mantovani, 1996) and careful analysis of the socio-cognitive aspects of the system requirement need careful development by engaging in dialogue with the stakeholders of the current and future systems. To some extent the recognition of the importance of the intelligence team has been recognized in other domains such as emergency command and control (Artman and Waern, 1999) where the more detailed analysis of interactions has been applied to similar processes.

There are cases where communication support systems, that form a large part of the intelligence network, have decreased the overall levels of cooperation and consensus building, undermining coordination and effective resource management (Wickens, Gordon and Liu, 1998). It is perhaps not surprising that more information can increase the quality of decision making and yet it can decrease the confidence and satisfaction of the group members. According to theoretical model of skilled performance perception proposed in this paper more information could induce anxiety concerning the ability to encapsulate and process relevant information, producing uncertainty. Any individual might deal with a limited part of the information array and as a consequence they might not feel the final decision represents their views effectively. This uncertainty can be managed by organizational or argumentative means. Thus, extending the discussion might help resolve differences as all the relevant items of information are examined in turn and the interpretations and actions considered, or someone may be nominated as the final decision maker who can arbitrate. Arbitration may be a necessary process in time-limited safety or mission critical decision-making in dynamic environment.

Often practitioners forget that battlefield information systems simply reveal a representation of the force disposition and capability of the enemy. This image of the current situation is complicated by the use of enemy tactics such as the use of jamming (Dawes, 1999), decoys (Spick, 1999, 2000), dis-information, and novel strategies.

> "intelligence officers .... who were deceived by the evidence they had so conscientiously collected and collated, and who failed to interpret it correctly- the *misinterpreters*". Hughes-Wilson Col. J. (1999) Military Intelligence Blunders. p.15. London : Robinson Books.

Both the accuracy and spatio-temporal resolution of the imagery is limited by the capabilities of sensors and by the transmission bandwidth available. Thus, the operator in receipt of information must qualify the image by the application of knowledge to resolve the most likely interpretation of the image. Then in the same or in a subsequent process they must infer the enemy intent to establish a course of action. If the operator falls behind the curve in management of their own force disposition or application of their power then the gap between success and failure may narrow substantially.

Intelligence Systems in Team Contexts

It has been noted that same teams operate in variety of situations and coordination of these teams is critically important (Grimes, 2000). There are clearly a number of factors that can be assessed to help ensure the optimal method for sharing knowledge and information across the team.

First, if the timing of information sharing is critical this may determine the way in which information flow is managed and who receives what. Where time is critical, as in air warfare and individual operators are highly skilled it may be better to disseminate raw information more widely. However, the clients receiving the information should have the tools and the display formats appropriate to the task they are required to accomplish as part of the a composite package (Stapleton, 1999).

If timely receipt of information is critical then processing bottlenecks should be identified in all resources, men, cognitive capability and communication linkages. It is all too easy to consider the process of dispatching information as an automatic process and to fail to appreciate the skill involved in selecting, packaging and forwarding information. Only recently it has been publicly announced that JSTARS and AWACS (Anonymous, 2000). This may represent a growing awareness that AWACS and ASTOR, or the U.S. equivalent AWACS and JSTARS, in combination are an effective force-multiplier when crews are trained to use the systems in concert effectively (Anonymous, 1999).

Need to Know

A major issue in intelligence information collected from the battlefield concerns who needs to know and what they need to know. The reasons are numerous.

Knowledge of what one knows can be used inferentially to inject decoys and mis-information into the system to divert resources. The knowledge concerning what is known may indicate the sensor and communication capability of the total information system. By knowing the accuracy of the current image and its weaknesses it may be possible to conduct psychological and information war in which the deployment of resources in strength produces shock or information overloads.

For whatever reason, the use of intelligence information is usually restricted to specific groups. However, this focus on security may lead to under-utilization of the greatest battlefield asset, the distributed and situationally aware cognition of individual operators. No where is this more apparent than in the air warfare environment where small changes in position may change the level of cognitive demand on operators.

Imagine a large package moving across the Forward Line of Troops (FLOT) when the leading aircraft are challenged by the deployment of high capable fighter aircraft travelling fast and high. The lead elements of the package may be focussed on the rapidly advancing threat and modern missile systems bring them within target range very quickly. The elements bringing up the rear may be more aware of Surface-to-Air assets and conscious of the possibility of package elements being forced down into or around onto unseen SAM batteries. If all elements are privy to complete air picture through JTIDS or an equivalent system the response may be more effective. There may be subtle cues to the crews that what is unfolding is a SAM trap and on that basis and briefing they may formulate a more effective plan.

The free availability of the air picture mediated by information distribution on a secure network for all the operators may help to free resources and make the outcomes less subject to the possibility of communication jamming. The cognitive load associated with communication may be diminished and more resources may be available for the specialist roles of the elements of the package. Thus, hard and soft kill EW elements may provide effective cover for the package and the air and ground elements may have the confidence to progress or egress.

Communication is clearly vital in establishing good situational awareness and it has been suggested that free information exchange may help to compensate for limitations within teams (Bolman, 1979; Orasanu, 1990; Schwartz, 1990; Wegner and Simon, 1990). However, communication does not in itself guarantee superior performance (Cook, Campbell and Angus, 1998; Reid, 2000).

The key threat to effective dissemination is the cost of the individual systems making the information available on a secure network and the justification of that cost-cutting measure on the basis of security and prioritization of resources to where it is most required. From the evidence of recent conflicts it would seem that ground, and not the air threat, represents the most potent enemy asset. Both in Iraq and in engagements in the Former Republic of Yugoslavia it seems that that very few opposition forces will be able to effectively mount a coordinated air and ground defence against hostile aircraft for a variety of reasons. However, previous conflicts may not be representative of future operational requirements as the air warfare strategies evolve with knowledge drawn from previous encounters.

There is no doubt that the transfer of information from lower echelons upwards and from higher echelons downwards may create problems and:-

> "It is impossible not to feel some sympathy for those unfortunate commanders who just didn't know, *because someone with the information failed to pass it on.*" Hughes-Wilson Col. J. (1999) Military Intelligence Blunders. p.15. London : Robinson Books.

Misinterpretation can propagate these errors of information omission when higher echelons seek on information confirming their expectations or when lower echelons selectively prioritize information they feel is most pertinent to the current working hypothesis. It is well known that once formed a working hypothesis is difficult to change and it even occurs among those trained to refute hypotheses i.e. scientists (Gilhooly, 1982). The potential for biases and the use of heuristic short cuts in processing large volumes of information are well accepted (Huey and Wickens, 1993). It is possible that these errors may not propagate as effectively when all individuals have access to the raw data.

Capability and Intentions

> "Understanding the differences between a potential enemy's capabilities and his intentions is crucial to understanding the difficulties facing the purveyor of intelligence." Hughes-Wilson Col. J. (1999) Military Intelligence Blunders. p.5. London : Robinson Books.

In warfare it is easy to see the opposition as a monolithic force that one faces and interprets in a coherent way. In the past the strongly controlled Ground-Controller Intercept management of air warfare favoured by the Former Soviet Union was seen as a major weakness. However, no unitary asset on a battlefield can be treated as sharing a common goal of a centralised leadership because it is possible that they have developed alternative strategies. Indeed, the priority goal of destroying the enemy command and control are likely to ensure that the approach taken by different enemy units is likely to be more fragmented and less coordinated or planned. It might be argued that the lack of a decisive policy in Kosovo concerning targets created opportunities for the opposing forces to escape destruction and to ensnare coalition forces in traps (Ignatieff, 2000).

The centrality of leadership, in many frameworks of military analysis, seems to reinforce the tendency towards fragmentation, segmentation and compartmentalisation that may be indirectly supportive a social loafing (Brown, 2000; Hartley, 1999; Latane, Williams, and Harkins, 1979) a phenomenon known to be counter-productive in group interactions.

The important issue in considering these outcomes is the consideration of who is best qualified to interpret the enemy actions, the crew at the front or the fighter controller circling some distance behind the FLOT.

Interpretive Skill and Self-Monitoring

There may be a tendency to focus on certain cues from the developing intelligence in information systems and for this to generate less than optimal performance as a consequence of risky decision making or conservative decision. This tendency has been noted elsewhere in the social psychological literature where faulty decision making based on a risky shift, over-optimism, Groupthink and polarisation (Brown, 2000, Hartley, 1997) are well recognized.

Sir Richard Johns (Chief of the Air Staff) has warned against the possible deluge of information and the slow transfer of information to where it is needed (Penney and Doke, 1999). Sir Richard has stressed that "intelligence must be 100% reliable so that it can be passed rapidly to the targeting and attack systems". This view follows the tenor of the view regarding the use of JSTARS for guiding air-to-ground operations and UAV aircraft for Battle Damage Assessment (BDA) in the Gulf War. Implicitly it suggests that the capture process should reduce the need for interpretive action or information management, that might slow down the process of converting information advantage into tactical advantage.

The dissemination of information is a key issue in the development of battlefield information management systems. The doctrine and policy adopted may significantly affect the performance outcomes and the resource utilisation. It has generally been agreed that there are difficulties in field operations in distributing information and that may be significant in co-ordinating and articulating the different elements of the total force package.

> "It has gotten better, but we still can't get down to the company level what they need to do the job". The coalition forces succeeded in the Gulf, but the contribution of intelligence during the battles was sometimes far from the definition of accurate information passed in a timely fashion to decision-makers to enable them to make correct decisions." Hughes-Wilson Col. J. (1999) Military Intelligence Blunders. p.5. London : Robinson Books

The concerns with distribution of information were echoed in discussions with Stapelton (1999) who suggested that all the elements of force package would benefit from a knowledge of force disposition if it were presented directly to the operator in the appropriate format. It was underlined that the reliance on voice communications for some members of the total package strength was potentially damaging in two ways. First, the groups with better situational awareness (SA) had to work harder to promote SA in the out-group and this added to their workload. Second, those without systems promoting SA were less effectively coordinated and articulated in the package encouraging independent action which was less than optimal in terms of the total battlespace. Thus, the introduction of partial deployment would be counter-productive and may in some circumstances generate greater losses.

The move to deployment of Beyond Visual Range (BVR) weaponry by coalition and opposition assets made information dissemination a priority issue (Kromhout, 1999) . expression of command intent and authority could be muted by the ineffective deployment of weapons systems in an environment where concerns about fratricide and colateral damage were high, as they normally are in peace-keeping, NATO and UN force deployments. The move to beyond visual range weaponry has been accompanied by increasing sophistication of the cockpit environment (Coombs, 1999; Aviation Week and Space Technology, 1996) and the avionic systems supporting the pilot (Gunston, 1990; Rendall, 1997). At the same time the number of operators involved in the system has shrunk to increase the workload on those remaining and this makes team-effectiveness an even more important element of the force equivalent equation. Cooperative and articulated asset use enables higher performance outcomes from the same absolute number of assets and it should decrease risk of losses.

It is clear that no matter how much the system is optimised the operators, in Airborne Command and Control (ACC) systems or in the front-line need training to intelligent execute the actions implied by the interpretation of the information. There is no doubt that the whole process could be automated but the danger would be friendly fire mishaps, colateral damage and political disintegration of coalition forces.

Sir Richard Johns' views concerning the confidence in the information presented are mirrored by concerns from Artman (1999b) who noted that operators who lack confidence in their sensing will either spend time cross-checking the information they receive or they will fail to use it effectively. These domain specific issues are a strong indication that problems concerning trust, confidence and uncertainty raised elsewhere (Thimbleby et al., 1994) are endemic to information systems.

Cook (1999a, 1999b) has proposed that confidence, trust and uncertainty are psychological properties of all physical systems in military usage and they can distort decision making. Given the model presented earlier concerning the strategic allocation of cognitive resources in experienced operators and their aversive experience of uncertain situations, or knowledge-based modes of information processing, it seems possible that strategic management of workload may be guided by affective cues and cognitive resource gradients.

It is surprsing that in complex control situations it may be possible for operators to fail to notice significant differences in the expected and the experienced conditions if the appropriate tools are not available to aid the comparison (Wood, 2000). This suggests that most operators would have only a broad brush impression of the situation and this is confirmed by the analysis of situational awareness in complex command and control situations (Grimes, 2000).

Conclusions

The use of technology to dominate the battlefield is a large part of the most recent conflicts:-

"The second element was provided by computers. When linked up to surveillance satellites as well as spy planes, computers increase the information to the commander and if – a big if – this information can be digested and compressed into timely knowledge of the enemy's dispositions, computers can improve a commander's capacity to react in real time." Ignatieff (2000) Virtual War, London : Chatto and Windus, p. 171.

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